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by

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This paper describes the current research program on flexible membrane liners (FML's) being conducted by the U.S. Environmental Protection Agency's (EPA's) Office of Research and Development (ORD). Three main program areas are discussed--prediction of service life based on liner-waste compatibility and liner resistance to various waste chemicals, installation requirements for FML's, and field verification. Also examined are the cooperative efforts of EPA, the liner industry, and the user community to develop the full potential for FML use in waste management facilities.

INTRODUCTION

Hazardous waste regulations for the Resource Conservation and Recovery Act (RCRA) of 1976 have been promulgated by the U.S. Environmental Protection Agency. These regulations suggest that flexible membrane liners (FML's) are to be used for certain kinds of waste management facilities. The Office of Research and Development (ORD) continues to support the development of these regulations through a dynamic FML research program. Major emphases are

service life prediction based on liner-waste compatibility and liner resistance to wastes, improved field installation procedures, and long-term maintenance in the field.

RCRA applies to all landfills, surface impoundments, waste piles, and land treatment units used to treat, store, or dispose of hazardous waste. The design and operating standards of the Act require all these facilities (except land treatment units) to have liners that prevent the migration of waste or waste components (leachate) into the subsurface (soil, groundwater, or surface water) during the active life of the facility.

The use of FML's in waste management facilities provides the necessary barrier for preventing waste migration. But other components such as the leachate collection and removal system must also be incorporated in the overall design to ensure contaminant control in case one of the components fails.

Great care must be taken in selecting FML's as design components of hazardous waste facilities. Both their benefits and limitations must be fully appreciated for designers to achieve the greatest potential of these materials. To help users realize this objective, ORD has undertaken a substantial research program to improve our knowledge of how FML's function and react under a variety of physical, chemical, and biological conditions.

DESCRIPTION OF THE RESEARCH PROGRAM

The ORD FML research program was initiated in 1973 after users raised serious questions about the useful lifetimes of liners that had undergone only brief periods of laboratory testing. Such liners needed to last for tens of years in the field, but their test exposures had been limited to less than 2 weeks in small beakers. The early research program was directed primarily at developing a protocol for evaluating FML's exposed to wastes. Two major projects (1, 2) developed a data base of information on the reaction of FML's exposed to municipal and industrial wastes. The major conclusions of these projects were that (a) municipal and industrial wastes can be successfully contained by FML's, and (b) successful waste containment with FML's requires that these liners be pretested by exposing them to the actual waste to be contained.

These results prompted EPA to develop a multifaceted approach to determine whether FML's could be used with confidence in waste management facilities to protect both the public health and safety and the environment. Major program areas defined were the prediction of service life based on liner-waste chemical compatibility and liner resistance to various waste chemicals, installation requirements and procedures (including seams), and field verification. Each program area is defined here briefly.

Chemical Compatibility and Resistance

In this program, FML samples are exposed to wastes or simulated wastes (e.g., in a project with the National Sanitation Foundation, CR810727)*, followed by measurements of physical properties as a function of time and temperature. This phase of the program emphasizes understanding the results and interpreting the data. The rate of change suggests, but may not directly determine, whether the FML material is compatible with the waste to which it is exposed. Another approach (Drexel University, CR810977) being evaluated is the relationship between resistance to chemical modification and change in permeability of FML's. These characteristics will then be related to the service life of a liner system when exposed to chemical attack.

Chemical resistance test data from other uses of polymeric membranes (protective clothing, food packaging, etc.) are being evaluated (A.D. Little, Inc., 68-01-6160) to determine their applicability to FML's of similar composition used in waste management. Along with this project, the basic chemistries (comparable solubility parameters) of the geomembrane and waste streams are being evaluated to determine whether chemistry alone can be used to predict compatibility.

*Contract awarded to institution and contract number.

Placing soil and soil-like materials over a liner exposed to chemicals is being evaluated as a means to increase service life. Early exposure tests suggested that this approach would decrease the chemical attack on the FML's. This subject was also suggested for research in a peer review of the liner research program. A study (Bureau of Reclamation, AD-14-F-3-A411) has been initiated to evaluate depth and type of coverings needed to obtain the benefit.

Future research activities on chemical compatibility and resistance appear promising. For example, the use of solubility parameters, hydrogen bonding indexes, and relative polarities have proved useful in the rubber and protective clothing industries for predetermining the compatibility of tank linings, hydraulic hoses, and piping within plants and for chemical warfare agents that may degrade clothing. As noted earlier, the technology is being re-examined to determine whether predictions can be made for FML and waste compatibility and for service life.

The research program is currently evaluating the Experts' System for determining chemical compatibility. This computer-based system is based on decisions being made on chemical compatibility by experts within the industry, particularly where no definite criteria exist and decisions are based largely on experience or judgment. This concept has been successfully used by the medical profession in diagnosis and by geologists in locating promising areas for exploration. The system is not hooked into any specific decision path; rather it can choose from alternative paths to develop conclusions. The line

of reasoning can be displayed on request in human language form. Locating experts may be a greater problem than programming the computers.

Installation Requirements and Procedures

Soil Foundation and Placement Practices--

Once an FML has been selected for a site, other problems arise. Guidance is needed on soil bedding conditions and current placement practices. Projects have been conducted in these areas (3, 4) to provide users with information on how FML's are best handled in the field and what conditions are necessary for the soil foundation.

Seaming--

Current projects include the development of seaming criteria (Bureau of Reclamation, AD-14-F-3-A411). This project will compare the strength and durability of seams that are fabricated according to the manufacturer's recommendations under ideal laboratory conditions and those that are constructed at disposal facilities by installation contractors. In this project, seams are being exposed to chemicals for various periods of time and evaluated for changes in bonding and strength. Accelerated weather exposure of the seams is also being evaluated.

Leak Detection and Repair--

The potential for leakage through tears, parted seams, pin holes, etc. is being evaluated (Texas A&M, CR810940) for several FML types and thicknesses and various hydraulic head and sub-base conditions. Development of actual data on leakage rates should help determine what degree of quality control (quality assurance/quality control) is needed during liner construction and when imperfections must be corrected.

For those liner systems already in place and for future identification the ORD research program is developing leak detection techniques. Time domain reflectrometry (TDR) and acoustic emission monitoring (AEM) (EarthTech Research Corporation, 68-03-3030) have both been used successfully to locate known leaks in an experimental pond. The TDR method is technically feasible for new sites, but it may be too expensive. The AEM method does detect the leak, but the acoustic level of the source decreases rapidly to a point that is difficult to distinguish from background noise. Both techniques are being re-evaluated for cost effectiveness and technical improvements that can be made. The electrical resistivity (ER) technique (Southwest Research Institute, 68-03-3033) has demonstrated its ability to locate 1-, 5-, and 12-in.-diameter leaks in a 1-acre pond filled with water. Both single and multiple leaks were detected. Tests are continuing to determine the effects of liquid depth and to correlate ER response to leak size.

The repair of leaks in situ is the objective of another study (EarthTech Research Corporation, 68-03-1714). The project has identified several grouts and procedures that could be used for repairing known leaks.

Future Research--

Future activities in the area of liner installation include determining the effects of upward hydrostatic forces on liner integrity and of long-term point loading. Placing soils on membrane surfaces at steep slopes will also be evaluated. The intent is to determine the conditions under which the soil starts to slide off the membrane and the measures necessary to correct the condition. Future studies may also evaluate the use of geotextiles and plastic nets to increase soil cover stability for steeper side slopes.

Quality control and quality assurance (QA/QC) will be addressed. Though it is not difficult to develop a design for a waste management facility, it is very difficult to achieve that design in the field. Experience has shown that a good QA/QC plan must be developed and implemented for all phases of construction.

FML's are being used more frequently for upgrading existing facilities that may be leaking. Existing and new facilities may require mechanical connections (e.g., to drain pipes). Future studies will systematically review such connections for consistency of performance and application.

Though FML's are not considered as structural members of the facility, their physical properties can be used to prevent problems. The use of FML physical properties will be reviewed to identify their limitations in design of land based waste management facilities.

Field Verification

Most ORD research on FML's has been conducted in the laboratory at the bench scale, but samples exposed in the field have been positively correlated with laboratory-exposed samples (6). Other field data are being collected to determine why systems failed or succeeded (A.D. Little, Inc., 68-03-1771; Woodward-Clyde, 68-03-1772). Improved procedures for compatibility testing, placement, and field maintenance of FML's will be identified by these results.

Since field sites represent real-world conditions, it is necessary to obtain samples that represent these. Each site is unique and presents a different challenge to the membrane. The ORD research program continues to seek sites that have failed, are being retrofitted, are decommissioned, or otherwise offer samples that can yield long-term performance data.

TECHNICAL RESOURCE DOCUMENT

Research results from ORD, manufacturers, and users and information from other related industries have been combined into a single document (6). This document is perhaps the single most comprehensive report on the use of FML's

in waste disposal. The data will updated and revised periodically as research and field results become available.

INDUSTRY PARTICIPATION

From the beginning, the ORD liner research program has been conducted with the full participation of industry. They have offered materials and information, and they have suggested ideas that could be mutually explored to improve the credibility of FML's.

The Agency has a strong policy regarding the quality of its research and reports. Industry has contributed considerable time and effort to helping conduct program reviews and to assessing the quality of Agency reports. This excellent response has helped provide a more complete understanding of research results.

Perhaps the single most important contribution by industry is the participation and development of Standard 54, the FML standard recently published by the National Sanitation Foundation. Though it has been under development for 4 to 5 years, the standard will lead the way in instilling confidence in the user community that FML's can be used in waste management facilities as well as other applications. The standard is expected to be improved as additional information becomes available. Industry has already indicated its commitment by expressing a willingness to continue participating.

CONCLUSION

ORD's continuing research program on FML's is essential to expand their use for hazardous waste disposal and to assure that they will perform as designed. Continued support from industry is required for acceptance and growth of this technology.

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